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(54) **LIQUID CRYSTAL LENS AND LIQUID CRYSTAL LENS MODULE**

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CPC ***G02F 1/1343*** (2013.01); ***G02F 1/134309*** (2013.01); *G02F 2001/294* (2013.01)

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CPC . G02F 1/29; G02F 2001/294; G02F 2203/28; G02C 7/083; G02C 7/101
See application file for complete search history.

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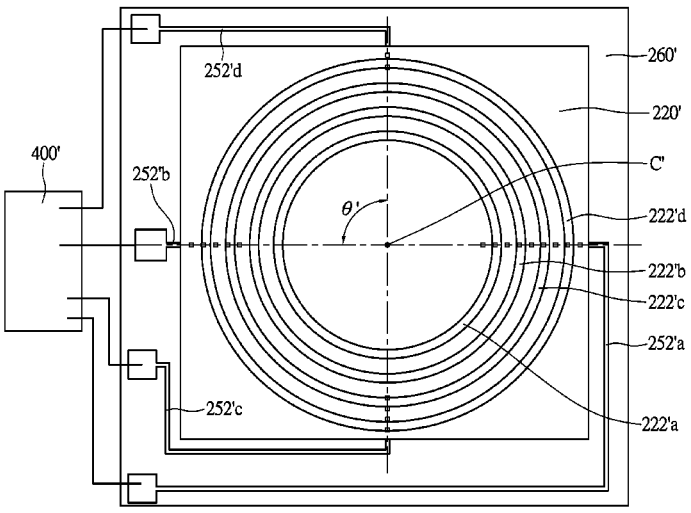
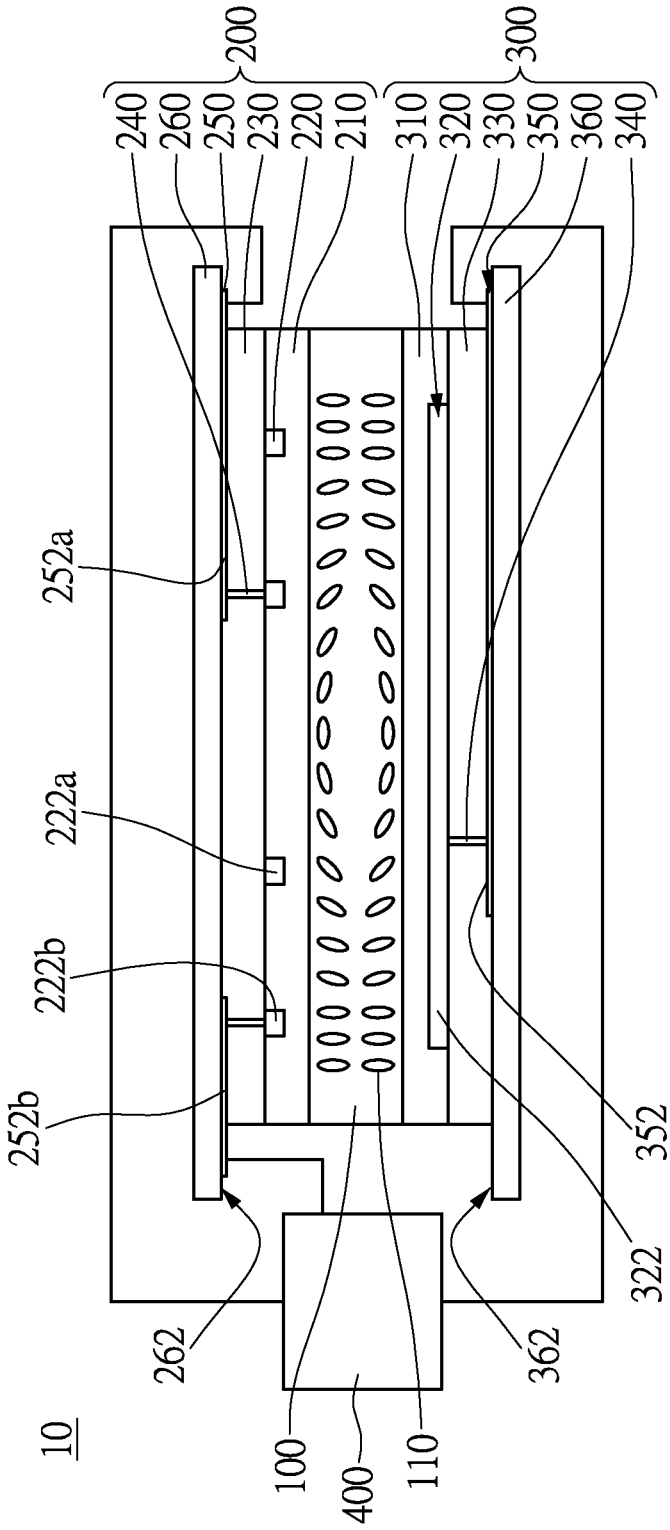
(57) **ABSTRACT**

A liquid crystal lens includes a liquid crystal layer and at least two driving electrode plates. The liquid crystal layer is arranged between the driving electrode plates. Each of the driving electrode plates includes a transparent substrate, a circuit layer, an insulating layer, an electrode layer, at least a conducting pillar and an alignment layer. The transparent substrate has a surface, and the circuit layer is atop the surface. The conducting pillar is arranged in the insulating layer and connected to the electrode layer and the circuit layer. The alignment layer contacts the liquid layer. The electrode layer is interposed between the alignment layer and the insulating layer. The electrode layer in at least one of the driving electrode plates includes at least two ring-shaped electrodes.

8 Claims, 4 Drawing Sheets

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110

FIG.1A

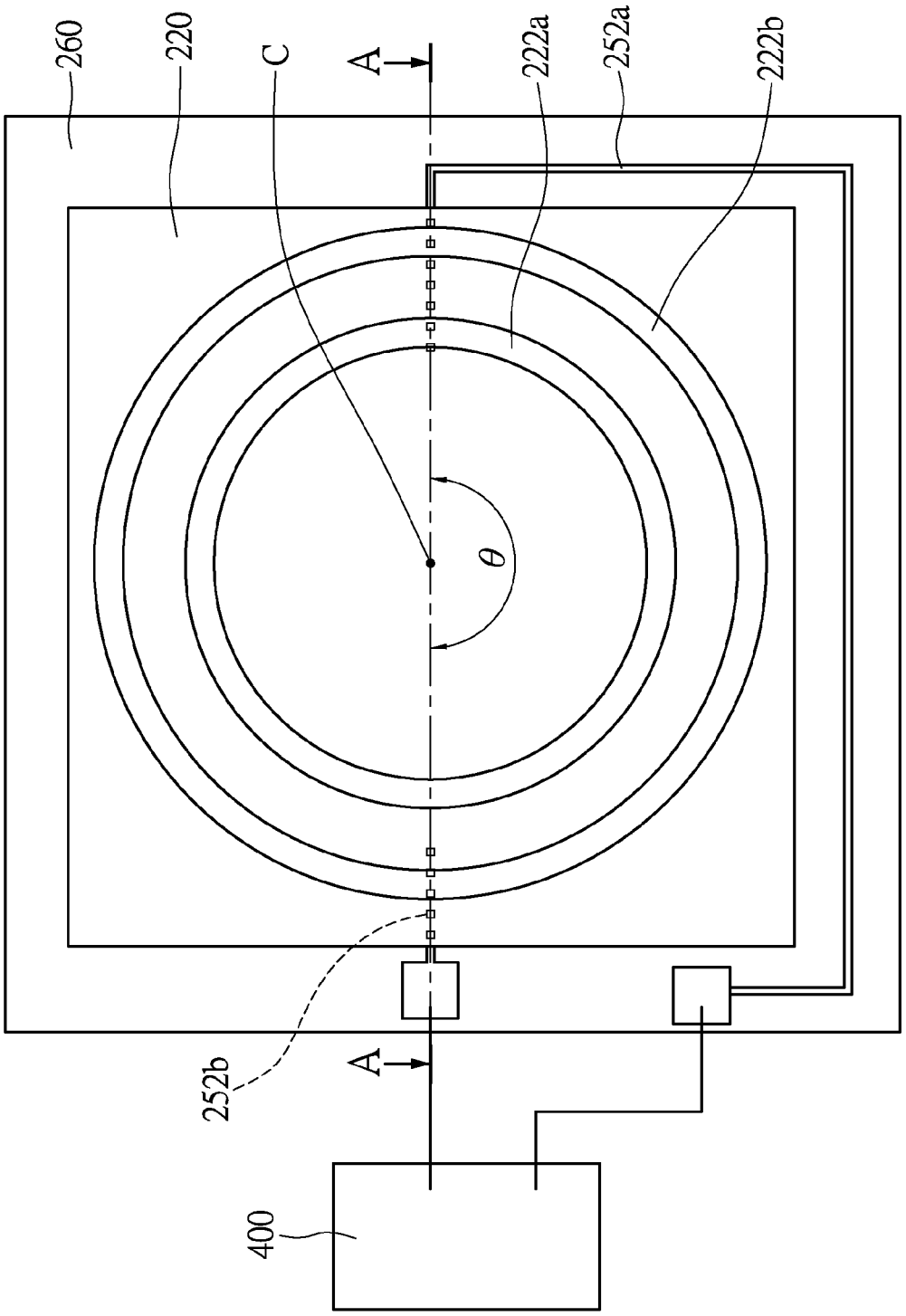

FIG.1B

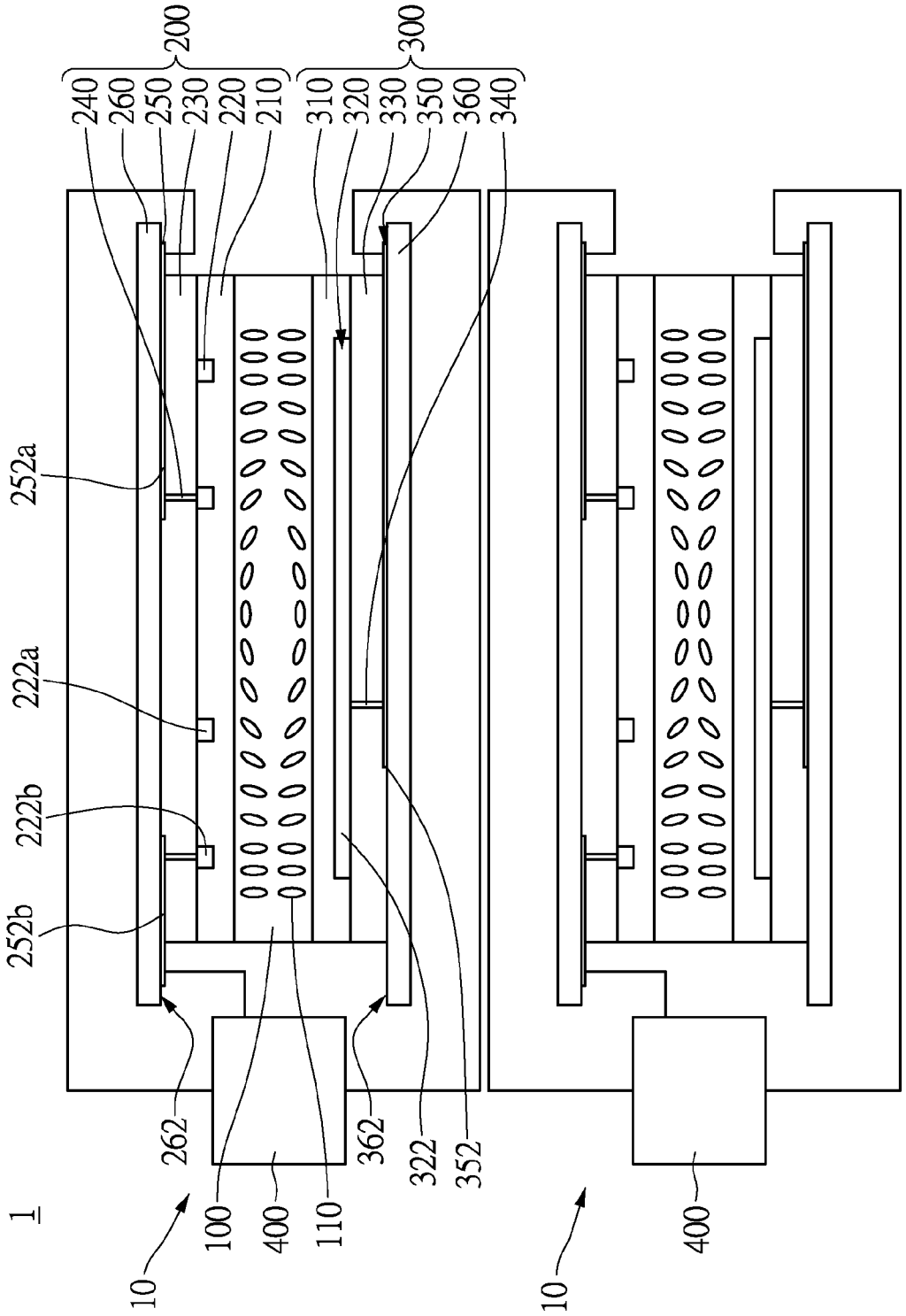
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FIG.1C

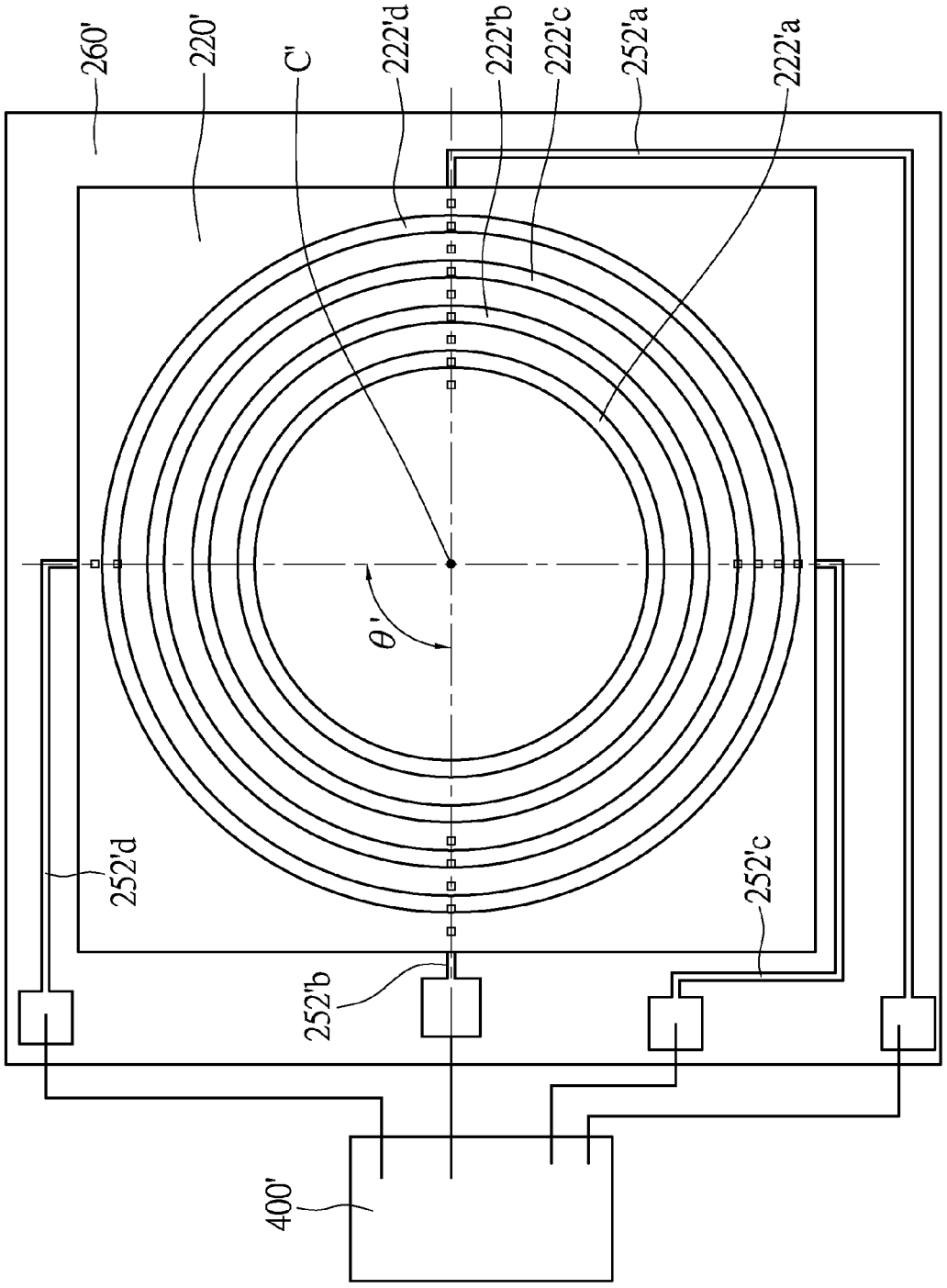

FIG.2

LIQUID CRYSTAL LENS AND LIQUID CRYSTAL LENS MODULE

BACKGROUND

1. Technical Field

The present invention relates to a lens and a lens module; in particular, to a liquid crystal lens and a liquid crystal lens module.

2. Description of Related Art

The liquid crystal lens is a lens which can change its focal length. The liquid crystal lens includes a liquid crystal layer, a pair of alignment layers, and a pair of electrode layers. The alignment layers position on the different sides of the liquid crystal layer respectively. The alignment layers can arrange the liquid crystal molecules of the liquid crystal layer in a predetermined way. The electrode layers are positioned on the different sides of the alignment layers respectively.

While the liquid crystal lens is in use, the voltage signal is applied to the electrode layers, so as to generate an electric field between electrode layers positioned on two sides of the liquid crystal layer. The electric field can control the rotation of the liquid crystal molecules in the liquid crystal layer. Thus, the rotated liquid crystal molecules can generate the effect similar to the optical lens. While light passes through the liquid crystal lens, light is affected by the arrangement of the liquid crystal molecules.

SUMMARY

The present invention provides a liquid crystal lens. While light passes through the liquid crystal lens, the liquid crystal lens generates similar effect as the optical lens.

The present invention provides a liquid crystal lens module. The liquid crystal lens module includes two adjacent liquid crystal lenses mentioned above.

The present invention provides a liquid crystal lens including a liquid crystal layer and at least two adjacent driving electrode plates to hold the liquid crystal layer. Each of the driving electrode plates includes a transparent substrate, a circuit layer, an insulating layer, an electrode layer, a plurality of conducting pillars, and an alignment layer. The transparent substrate includes a surface. The circuit layer is deposited on the surface. The insulating layer is disposed on and covers the circuit layer. The electrode layer is deposited on the insulating layer. The conducting pillars are positioned inside the insulating layer and connected to the electrode layer and the circuit layer. The alignment layer contacts the liquid crystal layer. The electrode layer is interposed between the alignment layer and the insulating layer. Besides, the electrode layer of at least one of the driving electrode plates includes at least two ring-shaped electrodes. One of the ring-shaped electrodes encircles the other ring-shaped electrode. The two ring-shaped electrodes have the same geometric center.

The present invention provides a liquid crystal lens module including two adjacent liquid crystal lenses mentioned above. Each of the liquid crystal lenses includes a liquid crystal layer and at least two adjacent driving electrode plates, so as to hold the liquid crystal layer. Each of the driving electrode plates includes a transparent substrate, a circuit layer, an insulating layer, an electrode layer, a plurality of conducting pillars, and an alignment layer. The transparent substrate includes a surface. The circuit layer is deposited on the surface. The insulating layer covers the circuit layer. The electrode layer is deposited on the insulating layer. The conducting pillars are positioned inside the insulating layer and connected to the electrode layer and the circuit layer. The alignment layer contacts the liquid crystal layer. The electrode layer are interposed between the alignment layer and the insulating layer. Besides, the electrode layer of at least one of the driving electrode plates includes at least two ring-shaped electrodes. One of the ring-shaped electrodes encircles the other ring-shaped electrode. The two ring-shaped electrodes have the same geometric center.

To sum up, the present invention provides a liquid crystal lens and a liquid crystal lens module. The driving electrode plate of the liquid crystal lens includes a circuit layer and an electrode layer. The circuit layer electrically connects to the electrode layer by utilizing the conducting pillars. The circuit layer and the electrode layer are positioned on different layers, thus the layout of the traces on the circuit layer would not limit to the design or the shape of the electrodes on the electrode layer.

In order to further appreciate the characteristic and technical contents of the present invention, references are hereunder made to the detailed descriptions and appended drawings in connection with the present invention. However, the appended drawings are merely shown for exemplary purpose rather than being used to restrict the scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the present disclosure, and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the present disclosure and, together with the description, serve to explain the principles of the present disclosure.

FIG. **1**A is a cross-section view of a liquid crystal lens in accordance with the first embodiment of the instant disclosure.

FIG. **1**B is a layout schematic diagram of one of the electrode layer in FIG. **1**A.

FIG. **1**C is a cross-section view of a liquid crystal lens module in accordance with the first embodiment of the instant disclosure.

FIG. **2** is a top view of the electrode layer in accordance with the second embodiment of the instant disclosure.

DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

FIG. **1**A is a cross-section view of a liquid crystal lens **10** in accordance with the first embodiment of the instant disclosure. Referring to FIG. **1**A, the liquid crystal lens **10** includes a liquid crystal layer **100**, at least two driving electrode plates and at least an external power supply **400**. The driving electrode plates are the main driving electrode plate **200** and the assisting driving electrode plate **300**. The main driving electrode plate **200** and the assisting driving electrode plate **300** are positioned on two sides of the liquid crystal layer **100**. In other words, the liquid crystal layer **100** is arranged between the main electrode plate **200** and the assisting driving electrode plate **300**.

Specifically, the main driving electrode plate **200** includes a transparent substrate **260**, a circuit layer **250**, a plurality of conducting pillars **240**, an insulating layer **230**, an electrode layer **220**, and an alignment layer **210**. The transparent substrate **260** includes a surface **262**. The circuit layer **250** is deposited on the surface **262**. The circuit layer **250** includes two traces **252***a*, **252***b*. The insulating layer **230** covers the circuit layer **250** and the surface **262**. The insulating layer **230** can avoid short circuiting between the traces. The electrode

layer **220** is deposited on the insulating layer **230**. The electrode layer **220** includes at least two ring-shaped electrodes **222***a*, **222***b*. The number of the ring-shaped electrode is equal to the number of the trace. In addition, the ring-shaped electrode **222***b* can encircles the other ring-shaped electrode **222***a*. The ring-shaped electrodes **222***a*, **222***b* have the same geometric center C. The distance between inner diameter of the ring-shaped electrode **222***b* and outer diameter of the other ring-shaped electrode **222***a* is 0.1 mm. Nevertheless, the present invention doesn't limit to the distance between the ring-shaped electrodes **222***a* and **222***b*.

The conducting pillars **240** are positioned inside the insulating layer **230** and electrically connected to the electrode layer **220** and the circuit layer **250**. Specifically, the ring-shaped electrode **222***a* electrically connects with the trace **252***a* by the conducting pillars **240** and the ring-shaped electrode **222***b* electrically connects with the trace **252***b* by the conducting pillars **240**. In other words, in the present invention, the traces **252***a*, **252***b* and the ring-shaped electrodes **222***a*, **222***b* are deposited on different layers. Thus, the layout of the traces **252***a*, **252***b* on the circuit layer **250** would not limit to the design or the shape of the ring-shaped electrodes **222***a*, **222***b* on the electrode layer **220**.

Referring to FIG. **1**B, FIG. **1**B is a layout schematic diagram of one of the electrode layer in FIG. **1**A. It's worth noting that, the following description is about the ring-shaped electrodes **222***a* and **222***b* of the main driving electrode plate **200** in the present embodiment, thus FIG. **1**B only show the electrode layer **220**, the circuit layer **250**, the transparent substrate **260** and the external power supply **400**. In addition, the cross-section view of liquid crystal lens **10** in FIG. **1**A is provided based on a section line A-A cutting through the liquid crystal lens **10** as shown in FIG. **1**B.

As shown in FIG. **1**B, the ring-shaped electrode **222***b* encircles the other ring-shaped electrode **222***a*. The ring-shaped electrode **222***a* and ring-shaped electrode **222***b* have the same geometric center C. In addition, the ring-shaped electrode **222***a* is electrically connected to the trace **252***a* of the circuit layer **250** and other the ring-shaped electrode **222***b* electrically connects with the trace **252***b* of the circuit layer **250**. It's worth noting that, the two traces **252***a*, **252***b* of the ring-shaped electrodes **222***a*, **222***b* distribute in the isometric way about the geometric center C. The number of the trace is two, thus the angle θ between the traces **252***a* and **252***b* is 180 degree. The traces **252***a*, **252***b* are distributed in the isometric way, thus the traces **252***a*, **252***b* do not gather at the same side. The traces **252***a*, **252***b* connect to the power supply from different positions. While the external power supply **400** supplies the voltage to the ring-shaped electrodes **222***a*, **222***b*, the effect of the non-uniform electric field caused by the concentrated voltage can be reduced.

Referring to FIG. **1**A, the alignment layer **210** deposits on the insulating layer **230** and covers the insulating layer **230** and the electrode layer **220**. The ring-shaped electrodes **222***a* and **222***b* are interposed between the insulating layer **230** and the alignment layer **210**. In addition, the alignment layer **210** contacts the liquid crystal layer **100**, so as to make the liquid crystal molecules **110** of the liquid crystal layer **100** arrange in the predetermined way.

Moreover, the structure of the assisting driving electrode plate **300** is similar to the structure of the main driving electrode plate **200**. The assisting driving electrode plate **300** also includes a transparent substrate **360**, a circuit layer **350**, a plurality of conducting pillars **340**, an insulating layer **330**, an electrode layer **320**, and an alignment layer **310**. The arranged method of each layer is omitted thereof. However, different from the main driving electrode plate **200**, in the present embodiment, the electrode layer **320** only includes an electrode **322** and the circuit layer **350** only includes a trace **352**. The electrode **322** electrically connects to the trace **350** via the conducting pillar **340**. In the present embodiment, the trace **352** and the electrode **322** are in the different layers, thus the layout of the trace **352** on the circuit layer **350** would not limit to the design or the shape of the electrode **322** on the electrode layer **320**.

The external power supply **400** electrically connects to the circuit layers **250**, **350**. The external power supply **400** controls the electrode **322** via the trace **352** and controls the ring-shaped electrodes **222***a*, **222***b* by the traces **252***a*, **252***b*, so as to generate the electric field between the electrode **322** and the ring-shaped electrodes **222***a*, **222***b*. Thus, the liquid crystal molecules **110** of the liquid crystal layer **100** are rotated by the influence of the electric field. As shown in FIG. **1**A, in the present embodiment, the shape of electrode in the electrode layer **220** is ring-shaped. Once voltage is applied, the refractive index of the liquid crystal molecules **110** can be changed to resemble the optical effect similar to the convex lens. In addition, the curve ratio of the arranged liquid crystal molecules **110** can be controlled by the supplying voltage.

It's worth noting that, in other embodiment, the electrode **322** can be the ring-shaped electrode, and the number of the electrode **322** can be more than one. The present invention is not limit to the number of the electrode **322**. The number of the trace **352** can be the same as the number of the electrode **322**. While the electrode **322** is the ring-shaped electrode, the layout method of the trace **352** can be the same as the layout method of the traces **252***a*, **252***b* in the main driving electrode plate **200**.

Next, referring to FIG. **1**C, FIG. **1**C is a cross-section view of a liquid crystal lens module **1** in accordance with the first embodiment of the instant disclosure. In actual operation, the single liquid crystal lens **10** might encounter issue regarding birefringence, thus the user can improve the problem by utilizing the liquid crystal lens module **1**. Referring to FIG. **1**C, in the present embodiment, the liquid crystal lens module **1** includes two adjacent liquid crystal lenses **10**. In other embodiment, the two liquid crystal lenses **10** are arranged in the transmitting path of a light.

The structure of the each of the liquid crystal lenses **10** is similar to the above mentioned and the description of the liquid crystal lenses **10** are omitted thereof. In actual operation, the external power supply **400** is utilized to drive the liquid crystal molecules of the two liquid crystal lens **10** to arrange in different form. For instance, the external power supply **400** can control the liquid crystal lens **10**. The refractive index of the liquid crystal molecules **110** in the liquid crystal lens **10** near the light source is changed to resemble the optical effect similar to the concave lens. On the other hand, the refractive index of the liquid crystal molecules **110** in liquid crystal lens **10** away from the light source is changed to resemble the optical effect similar to the convex lens. Therefore, issue regarding birefringence can be eliminated. In addition, in other embodiment, the liquid crystal lens module can also include a liquid crystal lens and a polarizer to eliminate issue regarding birefringence. The present invention doesn't limit the method to eliminate issue regarding birefringence.

It's worth noting that, the liquid crystal lens **10** can generate the effect similar to the optical lens by changing the rotation of the liquid crystal molecules **110**. While light passes through the liquid crystal lens **10**, the liquid crystal lens **10** can converge or diverge the light. Thus, in the present embodiment, the material of every one of the layers in the liquid crystal lens **10** can choose the transparent material, so as to allow light to pass through the liquid crystal lens **10**. For

example, the material of the insulating layers **230**, **330** can be the silicon nitrogen compound (SiNx), silicone compound (SiOx), resin, polyimide, organic insulating material, or an inorganic insulating material. The material of the alignment layers **210**, **310** can be polyimide.

In addition, the material of the traces **252***a*, **252***b*, **352**, the electrodes **222***a*, **222***b*, **322** and the conducting pillars **240**, **340** can be gold, copper, aluminum, conductive metal, conductive alloy, or compound conductive layer with multiple metal layers, such as chromium copper, or aluminum molybdenum. Moreover, the material of the traces **252***a*, **252***b*, **352**, the electrodes **222***a*, **222***b*, **322** and the conducting pillars **240**, **340** can be a transparent conductive material, such as indium tin oxide (ITO), indium zinc oxide (IZO), or indium gallium zinc oxide (IGZO). However, the present invention is not limit thereof.

In addition, a thickness of every one of the layers in the liquid crystal lens **10** can also influence the effect of the light passing through the liquid crystal lens **10** and the intensity of the electric field driving the liquid crystal molecules **110**. In the present embodiment, a thickness of both the insulating layers **230**, **330** are 20-25 nm, and the thickness of both the alignment layers **210**, **310** are 35-40 nm. However, the present invention is not limited thereof.

FIG. **2** is a top view of the electrode layer **220'** in accordance with the second embodiment of the instant disclosure. Different from the previous embodiment, in the present embodiment, the electrode layer **220'** includes a plurality of ring-shaped electrodes **222'***a*, **222'***b*, **222'***c*, **222'***d*. The circuit layer **250'** includes a plurality of traces **252'***a*, **252'***b*, **252'***c*, **252'***d* (FIG. **2** demonstrates four ring-shaped electrodes and four traces). The ring-shaped electrodes **222'***a*, **222'***b*, **222'***c*, **222'***d* are electrically connected to the traces **252'***a*, **252'***b*, **252'***c*, **252'***d* by the conducting pillars. The external power supply **400'** is electrically connected to the traces **252'***a*, **252'***b*, **252'***c*, **252'***d* to supply voltage to the ring-shaped electrodes **222'***a*, **222'***b*, **222'***c*, **222'***d*. Thus, the liquid crystal molecules **110** are driven to rotate.

As shown in FIG. **2**, the ring-shaped electrode **222'***d* encircles the ring-shaped electrode **222'***c*, the ring-shaped electrode **222'***c* encircles the ring-shaped electrode **222'***b*, and the ring-shaped electrode **222'***b* encircles the ring-shaped electrode **222'***a*. In other words, the four ring-shaped electrodes **222'***a*, **222'***b*, **222'***c*, **222'***d* have the same geometric center C'. The traces **252'***a*, **252'***b*, **252'***c*, **252'***d* distribute in the isometric way about the geometric center C'. In other words, the number of the traces is four, and the angle θ' between the adjacent traces is 90 degree. Similarly, while the number of the ring-shaped electrode is n, the angle θ' between the adjacent traces is 360/n degree. Hereinafter, the n is positive integer greater than 2.

Furthermore, the traces **252'***a*, **252'***b*, **252'***c*, **252'***d* are distributed in the isometric way, thus the traces **252'***a*, **252'***b*, **252'***c*, **252'***d* do not gather at the same side. The traces **252'***a*, **252'***b*, **252'***c*, **252'***d* are connected to the power supply from different positions. While the external power supply **400** supplies voltage to the ring-shaped electrodes **222'***a*, **222'***b*, **222'***c*, **222'***d*, non-uniform electric field caused by the concentrated voltage can be reduced. Moreover, in the present embodiment, the distance between the outer diameter of the ring-shaped electrodes **222'***a*, **222'***b*, **222'***c*, **222'***d* and the inner diameter of the adjacent ring-shaped electrodes **222'***b*, **222'***c*, **222'***d* is 0.1 mm respectively. Nevertheless, in the other embodiment, the distance between the adjacent ring-shaped electrodes can be different. The distance may depended on the design of the lens. The present invention is not limit thereto.

To sum up, the present invention provides a liquid crystal lens and a liquid crystal lens module. The liquid crystal lens includes a main driving electrode plate. The main driving electrode plate includes a circuit layer and an electrode layer. The circuit layer is electrically connected to the electrode layer by the conducting pillars. The circuit layer includes two traces. The electrode layer includes two ring-shaped electrodes. The circuit layer and the electrode layer is deposited on different layers, thus the layout of the traces on the circuit layer would not limit to the design and the shape of the electrodes on the electrode layer. Furthermore, the traces distribute in the isometric way about the geometric center, thus the traces do not gather at the same side. While the external power supply supplies the voltage to the ring-shaped electrodes, the effect of the non-uniform electric field caused by the concentrated voltage can be reduced.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

What is claimed is:

1. A liquid crystal lens comprising:

a liquid crystal layer;

at least two driving electrode plates, wherein the liquid crystal layer is arranged between the adjacent driving electrode plates, and each of the driving electrode plates comprising:

a transparent substrate comprising a surface;

a circuit layer deposited on the surface;

an insulating layer covering the circuit layer;

an electrode layer deposited on the insulating layer;

at least a conducting pillar arranged in the insulating layer, the pillar connected to the electrode layer and the circuit layer; and

an alignment layer abutting the liquid crystal layer, wherein the electrode layer is interposed between the alignment layer and the insulating layer, wherein the electrode layer of at least one of the driving electrode plates comprises at least two ring-shaped electrodes, one of the ring-shaped electrodes encircles the other ring-shaped electrode, and the ring-shaped electrodes have the same geometric center;

wherein the circuit layer of one of the at least two driving electrode plates comprises n ring-shaped electrodes and n traces, the ring-shaped electrodes connect to the traces respectively, and the traces distribute in an isometric way about the geometric center, wherein n is positive integer and is larger than 2, and the angle between two adjacent traces is 360/n degree.

2. The liquid crystal lens of claim **1**, wherein each of the insulating layer of the driving electrode plate has a thickness of about 20-25 nm.

3. The liquid crystal lens of claim **1**, wherein each of the alignment layer of the driving electrode plate has a thickness of about 35-40 nm.

4. The liquid crystal lens of claim **1**, wherein a distance between an outer diameter of one of the ring-shaped electrode and an inner diameter of the adjacent ring-shaped electrode is about 0.1 mm, the outer diameter is smaller than the inner diameter.

5. A liquid crystal lens module comprising two liquid crystal lenses, the liquid crystal lenses arranged in the transmitting path of a light source, wherein the liquid crystal lens comprising:

a liquid crystal layer;

at least two driving electrode plates, wherein the liquid crystal layer is arranged between the two adjacent driving electrode plates, and each of the driving electrode plate comprising:

a transparent substrate comprising a surface;

a circuit layer deposited on the surface;

an insulating layer covering the circuit layer;

an electrode layer deposited on the insulating layer;

at least a conducting pillar arranged in the insulating layer and connected to the electrode layer and the circuit layer; and

an alignment layer abutting the liquid crystal layer, wherein the electrode layer is interposed between the alignment layer and the insulating layer, wherein the electrode layer of at least one of the driving electrode plates comprises at least two ring-shaped electrodes, one of the ring-shaped electrodes encircles the other ring-shaped electrode, and the ring-shaped electrodes have the same geometric center;

wherein the circuit layer of one of the at least two driving electrode plates comprises n ring-shaped electrodes and n traces, the ring-shaped electrodes connect to the traces respectively, and the traces distribute in an isometric way about the geometric center, wherein n is positive integer and is larger than 2, and the angle between two adjacent traces is 360/n degree.

6. The liquid crystal lens module of claim **5**, wherein each of the insulating layer of the driving electrode plate has a thickness of about 20-25 nm.

7. The liquid crystal lens module of claim **5**, wherein each of the alignment layer of the driving electrode plate has a thickness of about 35-40 nm.

8. The liquid crystal lens module of claim **5**, wherein the distance between an outer diameter of one of the ring-shaped electrodes and an diameter of the adjacent ring-shaped electrode is about 0.1 mm, the outer diameter is smaller than the inner diameter.

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